Journal of Herpetology, Vol. 29, No. 3, pp. 370–374, 1995

Movements and Submergence Patterns of Kemp's Ridley Turtles (*Lepidochelys kempii*)

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ABSTRACT.—Four Kemp's ridley (*Lepidochelys kempii*) turtles, ranging in straight-line carapace length from 51 to 60 cm and in weight from 19 to 27 kg, were released in 12 to 19 m water depths off Florida, Texas, and North Carolina and tracked for 1.0 to 8.5 months. Movements up to 2600 km were observed. The number of submergences per day was inversely proportional to the duration of submergences per day. These ridleys spent 89% of their time submerged and frequented waters ranging in depth from 1–140 m. Turtles ranged from inshore to 77 km offshore. Mean swimming speeds of these turtles were from 0.7 to 1.3 km/h, with over 95% of the actual velocity values ≤5 km/h.

The Kemp's ridley (*Lepidochelys kempii*) is the most endangered sea turtle. It reaches a straight-line carapace length (SCL) of 70 cm and maximum weight of 45 kg (Magnuson et al., 1990). Nesting occurs primarily at Rancho Nuevo, Taumalipas, Mexico, with a few additional nests occurring in Texas, Florida, and South Carolina. Kemp's ridleys are most abundant in coastal waters from Texas to Florida, but occur in moderate numbers along the eastern seaboard of North America to Nova Scotia (Pritchard, 1989). They have been reported in the British Isles, Netherlands, and France. Distribution, movements, and feeding habits of pelagic hatchlings are unknown. Collard and Ogren (1990) postulate that hatchling dispersal is driven by surface water currents. Ogren (1989) speculated that Kemp's ridleys remain pelagic until they are 20 cm. Juvenile Kemp's ridleys (20–60 cm SCL) occupy estuarine and shallow (<20 m) coastal waters, whereas adult ridleys (>60 cm SCL) remain mostly offshore in depths <50 m (Ogren, 1989).

Present day impacts of man's activities on sea turtles, including fishing (such as shrimp trawling [Caillouet et al., 1991] and gill netting [Magnuson et al., 1990]), dredging of navigable waterways (Dickerson et al., 1991), and explosive removal of offshore petroleum platforms (Klima et al., 1988), are disconcerting to conservationists. To protect ridleys it is essential to determine which habitats they select for use that place them at risk of injury or death. We must understand the life history of sea turtles and determine their stage-specific distributions. The purpose of this work was to describe the movements, diving behavior, and associations with coastal habitats of Kemp's ridleys to reveal areas where they are likely to be found. It was hypothesized that this species, excluding hatchlings, is predominately a coastal forager.

MATERIALS AND METHODS

One adult-sized and three subadult Kemp's ridley sea turtles, 51–60 cm SCL and 19–27 kg, were captured on U.S. commercial shrimping vessels in the Atlantic Ocean and the Gulf of Mexico. The subadults (K1–K3) were in captivity for four days or less prior to their release. The fourth turtle (K4), evidence for a federal court case, was held for one year at the turtle headstart facility of the National Marine Fisheries Service (NMFS) in Galveston, Texas. While in captivity, all turtles were maintained according to procedures developed by NMFS for captive rearing of sea turtles (Caillouet et al., 1993). Turtles were healthy and exhibited normal behavior during their captivity.

Satellite transmitters (PTTs) were packaged in rectangular polycarbonate cases 16.0 cm × 9.5 cm × 2.5 cm and secured with resin and fiberglass cloth to the second neural scute of each turtle (Renaud and Carpenter, 1994). This procedure is not harmful to sea turtles (Renaud et al., 1993). Total weight (817 g) of the package did not exceed 5% of any turtle's body weight. Information obtained from satellite transmitters included latitude and longitude of turtle, date and time of the location, ambient temperature, duration of the last dive, and the number and average duration of turtle submergences during 0800–1959 h (day), and 2000–0759 h (night) local time. PTTs transmitted data for 6-h periods, every other 6 h.

Sequence of movement was plotted for each turtle. Distance from shore and water depth were determined from satellite locations transposed onto nautical charts. Distances between consecutive locations were calculated for each turtle and estimates of swimming speeds calculated. Number of submergences, submergence duration, percent of time spent under water and ambient temperature were analyzed by season

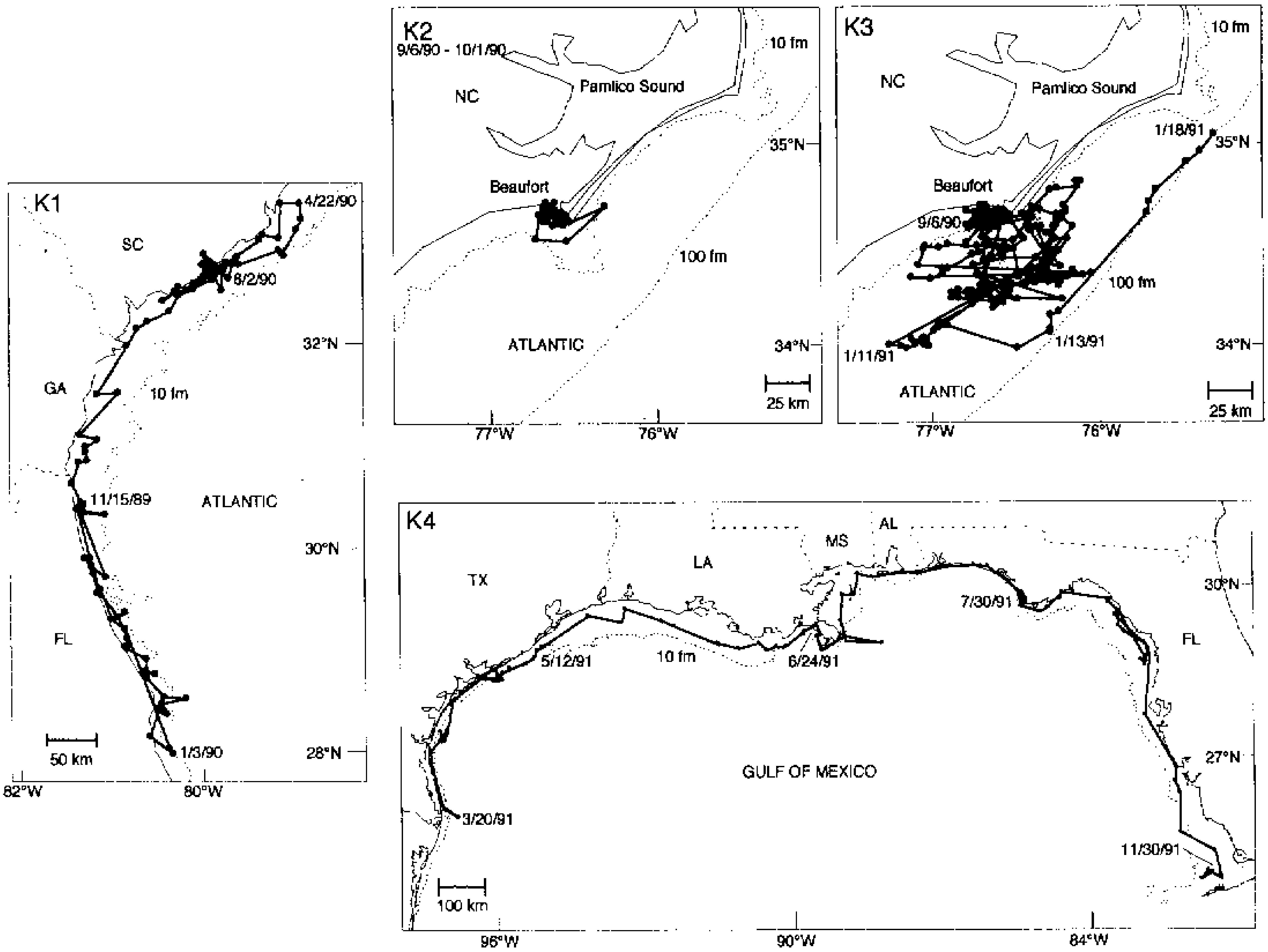

FIG. 1. Movement of K1 from November 1989 to June 1990, K2 from September 1990 to October 1990, K3 from September 1990 to January 1991, and K4 from March 1991 to December 1991.

(winter: December–February; spring: March–May; summer: June–August; fall: September–November) separately for each turtle, and for all turtles combined using the non-parametric Wilcoxon Test with alpha set at 0.05. Standard error was used to describe the variability around means.

RESULTS

Nearshore coastal movements were typical of all turtles during the spring, summer, and fall. Two turtles tracked in the winter moved offshore into warmer and deeper water. K1, released off Mayport, Florida, was tracked for 5.5 mo, 15 November 1989 to 3 June 1990 (Fig. 1). It travelled 270 km south in 49 d to an area 50 km south of Cape Canaveral, Florida. By the end of February K1 returned to Mayport, Florida. It continued northward and spent 11 d in Charleston Harbor, South Carolina during the first half of April. By late April, K1 was off Pawley's Island, South Carolina, 225 km north of its release site. It returned to Charleston Harbor for 7 d in May. Eighty-five percent of K1s locations were within the 18 m (10 fm) depth contour. It occupied areas having a mean depth of 11.7 ± 0.8 m and mean distance from shore of 10.3 ± 1.0 km.

K2 was released off Beaufort, North Carolina, and tracked for approximately one month, 6 September 1989 to 1 October 1989. Except for a short excursion inshore and another one 25 km to the north, K2 remained in Onslow Bay between the Beaufort Ship Channel and Cape Lookout (Fig. 1). Ninety-six percent of K2s locations were within the 18 m depth contour. It occupied areas having a mean depth of 9.2 ± 0.9 m and mean distance from shore of 3.4 ± 0.5 km.

K3, released off Beaufort, North Carolina with K2, was tracked for 4.5 mo, 6 September 1989 to 18 January 1990. It remained off Beaufort in Onslow Bay through late November. Movement offshore coincided with cooler winter waters moving into Onslow Bay. K3s last monitored position was in the Gulf Stream (120-m depth), 125 km NNE of its release site (Fig. 1). Twenty-nine percent of K3s locations were within the 18 m depth contour. K3 occupied areas having a mean depth of 25.5 ± 1.0 m and mean distance from shore of 30.9 ± 1.4 km. The high mean bottom depths and distances from

TABLE 1. Swimming speeds of turtles. N = number of locations used to determine a speed between points.

Turtle	N	Swimming speeds in km/hr			
		≤1	1.1–5.0	5.1–10	≥10.0
K1	97	75.3	24.7	0.0	0.0
K2	65	80.0	20.0	0.0	0.0
K3	210	57.1	38.1	4.3	0.5
K4	113	70.8	28.3	0.9	0.0

shore for K3 were due to time spent in the Gulf Stream off the coast of North Carolina during the winter.

K4, released off Brownsville, Texas, was tracked for 8.5 months, from 20 March 1991 to 4 December 1991. By mid-June the turtle was at the Mississippi Delta, 1130 km from its release site. The turtle was last recorded 56 km NNE of Key West, Florida (Fig. 1). During the 8.5 mo tracking period, K4 moved approximately 2600 km along the Gulf coast. Eighty-seven percent of K4s locations were within the 18 m depth contour. K4 occupied areas having a mean depth of 11.4 ± 0.9 m and mean distance from shore of 13.7 ± 1.2 km.

Swimming velocities for turtles ranged from 0.02–11.0 km/h. Overall mean velocity for all turtles combined was 1.0 ± 0.05 km/h. Mean swimming speeds for individual turtles ranged between 0.7 and 1.3 km/h. Speeds were ≤5.0 km/h 95.2–100% of the time (Table 1). Only one speed was calculated in excess of 10 km/h.

The turtles exhibited varied submergence patterns (Table 2). As a group, the mean number of submergences was lowest in summer (60.5 ± 4.3/night and 73.9 ± 6.8/day) and highest in winter (222.2 ± 27.3/night and 280.9 ± 26.3/day). Mean number of submergences for the spring was 99.4 ± 8.6 (day) and 56.7 ± 4.9 (night), and 82.1 ± 14.3 (day) and 76.9 ± 12.7 (night) in the fall. Although the number of submergences during the day was usually higher than at night, these differences were only significant for K1 in the spring.

Mean submergence time of all ridleys combined was 33.7 ± 2.5 min and ranged from 24.7–49.3 min for individual turtles. Submergences ranged from less than one min to a maximum of 7 h. Eighty-four percent of the submergences were ≤60 min and 96% were ≤180 min. K1 and K3 accounted for all 23 submergences exceeding 180 min. Mean submergence duration in the summer (17.0 ± 2.0 min) was significantly ($P < 0.05$) lower than mean submergences for all other seasons; fall = 41.1 ± 3.9 min, winter = 36.7 ± 6.3 min, and spring = 33.4 ± 5.5 min.

Mean daily submergence time (expressed in percent) for all Kemp's ridleys combined was significantly different among seasons. It ranged from a mean of 77.1 ± 2.5% during winter days to a mean of 96.7 ± 0.3% in spring days. Individually, mean submergence time ranged from 58.9% (K2, fall) to 98.5% (K1, summer). There were no day-night differences in percent of time submerged for any turtle in any season.

Internal PTT temperature was used to estimate the ambient water temperature surrounding each turtle. Except for K2, mean day and night water temperatures were not significantly different during any season, for all turtles combined or for individual turtles (Table 2). For K2, temperature was significantly higher ($P < 0.05$) at night than during the day in the fall. Mean seasonal water temperatures were significantly different from each other; spring 22.7 ± 0.2 C, summer 29.9 ± 0.2 C, fall 26.4 ± 0.3 C, and winter 20.4 ± 0.2 C. Highest mean temperatures (25.9–31.9 C), day and night combined, occurred from May through October with August having the largest values. Cooler mean temperatures (18.5–21.5 C) occurred from November through April with February having the lowest values.

DISCUSSION

Information on the tracking of Kemp's ridley sea turtles is limited in peer-reviewed journals. Timko and DeBlanc (1981) developed a tethered radio transmitter and monitored movements of yearling head started Kemp's ridleys for up to 30 d over a 70 km range off the southwest coast of Florida. Byles (1988) used radio tags to monitor two juvenile Kemp's ridleys for 7–15 wks in Chesapeake Bay, Virginia. These turtles exhibited habitat preferences for sea grass beds (*Zostera marina* and *Ruppia maritima*) and fed primarily on blue crabs. Mean dive duration was 12.7 min.

Kemp's ridleys in this study exhibited distribution patterns similar to those summarized by Magnuson et al. (1990), supporting the hypothesis that Kemp's ridleys are a nearshore species. Net movement from release sites ranged from 25–2600 km. The majority of turtle locations were within 15 km of shore and in water depths <18 m. Notable movement into areas of warmer water occurred for the two turtles tracked in the winter. K1 moved from the colder waters in north Florida to a warmer region south of Cape Canaveral and K3 moved into the Gulf Stream. Carr (1980) believed that air and sea surface temperatures are likely to influence sea turtle movement. Although these turtles displayed no significant site fidelity, behavioral observations on loggerhead (Renaud and Carpenter, 1994) and green (Renaud et al., 1995) turtles suggested that pronounced site fidelity may occur in other species.

TABLE 2. Number of dives, percent submergence time and PTT temperature for 12-hr day (D) or night (N) periods, by sea turtle by season. Values are means, rounded to the nearest whole number. A dash (—) indicates that no data were available.

Turtle		Winter		Spring		Summer		Fall	
		D	N	D	N	D	N	D	N
K1	Sample (N)	17	27	45	66	3	1	1	1
	No. dives	27	11	119	70	163	138	5	6
	Pct. submerged	94	96	97	97	98	99	97	97
	Temp. °C	19	20	22	22	27	27	21	21
K2	Sample (N)	—	—	—	—	—	—	13	9
	No. dives	—	—	—	—	—	—	149	54
	Pct. submerged	—	—	—	—	—	—	65	50
	Temp. °C	—	—	—	—	—	—	29	33
K3	Sample (N)	49	46	—	—	—	—	44	40
	No. dives	369	346	—	—	—	—	87	117
	Pct. submerged	71	69	—	—	—	—	89	88
	Temp. °C	21	21	—	—	—	—	24	24
K4	Sample (N)	—	—	11	27	32	60	25	38
	No. dives	—	—	20	25	66	59	42	42
	Pct. submerged	—	—	94	94	94	94	91	95
	Temp. °C	—	—	25	25	30	30	27	28

Swimming velocities (0.02–11.0 km/h) computed for these turtles were similar to velocities determined for loggerhead turtles in the Gulf of Mexico (Renaud and Carpenter, 1994) and to velocities calculated from Stoneburner's (1982) data on loggerhead movement. It is important to note that inherent errors in these speeds may be due to (1) the assumption of continuous straight-line movement, (2) error in satellite locations, (3) consecutive surfacings being out of satellite view, and (4) assistance or hinderance of water currents. Sea turtles may swim short distances, sleep, or backtrack toward earlier surface locations before surfacing again. Therefore, actual swimming speeds of these turtles may vary around the reported values.

The mean number of submergences for these turtles ranged from 60.5–280.9 min in the summer and winter, respectively. Increased diving activity in the winter exhibited by K1 and K4 is not typical of sea turtles (Renaud and Carpenter, 1994). K1 was moving south toward Cape Canaveral and K3 was apparently "searching" for warmer water in the Gulf Stream. Each of these behavioral patterns could account for increased diving and surfacing activity. Mean submergence duration was 33.7 min with 84% of the submergences $\leq$60 min. Submergences >180 min occurred in the winter and early spring and may be similar to hibernation described for loggerheads by Carr et al. (1981). Mean submergence times for Kemp's ridleys in our study were considerably longer than 16.7 min found by Mendonca and Pritchard (1986) for adult female ridleys. There is no reason to doubt the accuracy of submergence durations recorded by satellite transmitters; however, submergences >3 hr should be viewed with caution. Debris or algae covering the saltwater switches on PTTs could effectively keep the PTT in a dive mode while the turtle is on the surface. Mean daily submergence time ranged from 77.1–96.7%. Daily submergence time reported elsewhere was 96% for adult female ridleys in the Gulf of Mexico (R. Byles, Pers. Comm.) and 90.0–95.7% for satellite tracked juvenile loggerhead turtles in the Gulf of Mexico (Renaud and Carpenter, 1994).

Data from this study are useful for describing areas that turtles inhabit and where they are most vulnerable to fishing and other activities of man. The habitat of Kemp's ridleys (mostly <18 m water depths) overlaps with that of the commercial shrimp fishery, the greatest known source of sea turtle mortality (Henwood and Stuntz, 1987; Magnuson et al., 1990). Caillouet et al. (1991) showed a direct relationship between sea turtle strandings and fishing effort of the shrimping fleet between 1986 and 1989. A more detailed database on Kemp's ridley distribution may allow the promulgation of new fishery regulations which further protect this endangered species. Areas identified where ridleys are most likely to be found can provide a basis for maximizing the effectiveness of future studies on turtle stock assessment and ecology. This database needs to be more fully developed. To this end, the accumulation of information on the spatial and temporal distribution of Kemp's ridleys should have priority.

Acknowledgements.—The author would like to recognize Jo Williams for technical assistance with satellite data, file management and graphics, and to reviewers who provided helpful constructive comments on the original manuscript.

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Accepted: 8 April 1995.